DYNAMIC FINITE ELEMENT MODELING OF TRANSCRESTAL SINUS MEMBRANE ELEVATION FOR MAXILLARY BONE AUGMENTATION

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Introduction

Alveolar resorption following tooth loss frequently limits bone volume available for dental implant placement in the posterior maxilla. Maxillary sinus floor augmentation is routinely carried out via a lateral approach, however, associated with patient morbidity [Chiapasco, 2009]. Transcrestal surgical techniques for sinus membrane elevation have thus been developed [Summers, 1998], the minimally-invasive approach, however, carries an increased risk of membrane perforation [Lozada, 2011].

Methods

To accurately model the 4-dimensional process of transcrestal sinus membrane elevation [Huang, 2012] the biomechanical properties of maxillary sinus membranes were explored in human cadavers (Table 1). Computed tomographic scans of human maxillary sinuses of variable internal anatomy, including maxillary sinus septa [Pommer, 2012] were obtained. Sinus membrane elevation using osteotomes of various diameters was modeled and compared to force distribution in the course of membrane elevation by gel-pressure [Pommer, 2009b] using dynamic finite element analysis.

Results

Peak forces that increase the risk of maxillary sinus membrane perforation were seen around the tip of the osteotome used for membrane elevation (Figure 1). Larger osteotome diameters decreased the risk of iatrogenic membrane perforation (maximum elevation height 5.7 mm vs. 4.3 mm, $p<0.001$). Gel-pressure-mediated membrane elevation reduced the risk of membrane perforation significantly ($p=0.02$) due to even distribution of elevation forces.

Discussion

Avoidance of peak forces may help to reduce the rate of sinus membrane perforation, distribution of force, however, depends largely on sinus anatomy.

	One-dimensional elongation	***Two-dimensional elongation***
Membrane thickeness	*0.099 ± 0.056 mm*	*0.080±0.028 mm*
Burst elongation	*32.6 ± 12.3 %*	*24.7 ± 4.7 %*
Burst tension	*5.9 ± 2.5 N/mm²*	*8.6 ± 5.1 N/mm²*
Modulus of elasticity	*0.049 ± 0.019 GPa*	*0.070 ± 0.04 GPa*
Membrane adhesion	*0.050 ± 0.025 N/mm*	

Table 1: Biomechanical properties of the human maxillary sinus membrane [Pommer, 2009a].

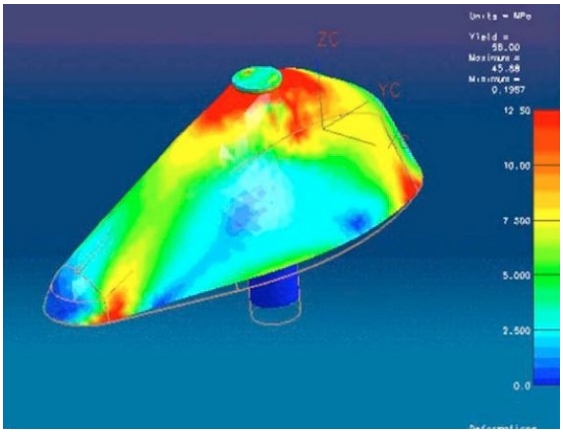

Figure 1: Finite element analysis revealed peak forced (red) around the tip of the osteotome used for membrane elevation.

References

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